Telephone Apparatus Springs[1]

A Review of the Principal Types and the Properties Desired of These Springs

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This article describes the types of springs employed in telephone apparatus and enumerates the engineering requirements both from the standpoint of mechanics and the quality of materials desired. The chemical and physical requirements of the spring materials are given. The importance of fatigue is emphasized and the endurance limit is given for spring brass, nickel silver and phosphor bronze.

THE proper functioning of telephone apparatus springs depends upon careful design and selection of material. In many instances the springs must occupy small space and maintain delicate adjustment throughout the life of the apparatus with a minimum of attention. Whereas the physical size of these springs is small, the forces are sometimes necessarily large due to space limitations and this requires careful choice of material. It is believed that the use of these small springs is not unique to the telephone art and a discussion of materials and methods of test used should have broad interest and application.

There are three general classes of springs employed in telephone apparatus. For the purposes of this discussion the springs may be classified as follows:

Springs of sheet non-ferrous metal
Springs of clock spring steel
Helical springs.

Sheet Non-Ferrous Springs

Sheet non-ferrous springs usually consist of punched and formed parts made from brass, nickel silver, or phosphor bronze. These serve as electrical contact carrying members that are deflected or operated either electromagnetically or mechanically. Such springs are essentially cantilever springs clamped at one end and bearing near the other end one or more precious-metal contacts that are spot welded in place. The precious-metal contacts are employed to reduce contact resistance and the destructive effects of arcing when circuits are broken. The apparatus employing such springs are keys

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of the switchboard type, relays, jacks, and interrupters. Certain apparatus known as switches employ these springs as brushes or wiping members. Here precious-metal contacts are not usually employed, but the ends of the springs must serve as contacting and wearing parts. Other springs are employed statically or, in other words, are required to maintain constant pressure for long periods without interruption. All springs that are attached to, or form part of, electrical circuits are soldered to connecting wires. This is usually done by soldering the wire or connection to a lug or projection that forms part of the spring. These lugs in most instances are on the opposite end of the clamped area from the operated end. The springs are almost always clamped between strips of phenol fiber because of its good insulating properties, mechanical strength, and permanency of form. A typical example of the use of the more common type of these springs is illustrated by Fig. 1 showing the familiar switchboard key.

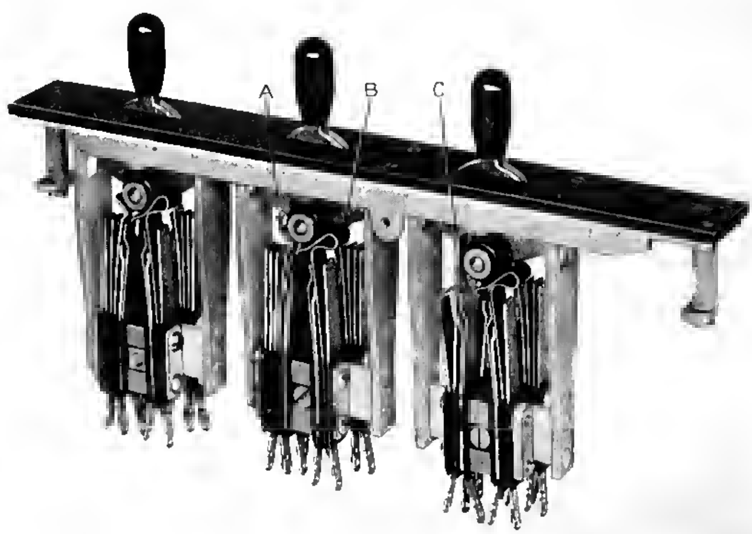

Fig 1—Common type of switchboard key illustrating use of sheet-metal springs: *A*, plunger spring with crimp; *B*, crook spring; *C*, straight plunger spring.

The properties required of these small springs which are numerous and vary for each type of application are summarized as follows:

The proportional limit must not be too high to prevent the spring's being adjusted by flexing it with a tool to the point where it takes a set and occupies a position where it provides the desired operating

pressure. In other words, there must be room enough to flex the spring to the point where it will take a set within the space provided. A spring of high proportional limit such as one of clock-spring steel may be bent nearly double without being permanently deformed. Obviously, such a spring could not be adjusted in the key shown by Fig. 1.

The modulus of elasticity should be within the range of 12,000,000 to 20,000,000 lb. per sq. in. in order that the load-deflection rate will not be too steep to permit reasonable ease of adjustment by hand.

The endurance limit must be high enough to permit satisfactory operation throughout the life of the apparatus. In cases where space limitation is a factor, reference must be made to the stress-cycle graph made for the material to determine if the spring may be expected to stand up in service.

Creep or deformation under sustained load must not take place since the material will lose tension. Brass, nickel silver, and phosphor bronze may be expected on the basis of years of experience to hold adjustments when stressed up to approximately their proportional limits. Other materials when considered for telephone apparatus springs are investigated to determine their "creep" characteristics.

Season cracking takes place with highly stressed brass under severe atmospheric conditions, and for this reason springs that are required to hold their pressures without being deflected for long periods are not made from this material. Nickel silver will also season crack under still higher stress, and phosphor bronze least of all. In designing these springs, generous fillets and easy curves are employed to prevent the building up of localized high stresses that may lead to season cracking under sustained load and fatigue failure under repeated flexure.

When these springs are used as wipers in electrical circuits where arcing can occur, brass and nickel silver are not employed for the reason that the heat of the arc breaks down the material, volatilizes the zinc, and disintegrates the metal. For this reason, phosphor bronze, which does not contain zinc and has superior wear resistance to brass and nickel silver, is employed.

In addition to the foregoing properties, these springs must be resistant to atmospheric corrosion and capable of being readily soldered with soft solder. Nickel silver, as may be seen from Table 2, is superior to brass in its mechanical properties and in addition may be readily spot welded. As a result of years of experience it has been found that springs made of this material are capable of maintaining adjustment in a satisfactory manner in service. Phosphor

bronze has still greater wear resistance than brass or nickel silver and superior spring properties.

The chemical compositions of brass, nickel silver, and phosphor bronze spring materials used for telephone apparatus are shown in Table 1 and the mechanical properties are given in Table 2. The range of tensile strength and hardness shown comprises the specification limits. A more detailed description of the properties of sheet brass has been given elsewhere.[2]

TABLE 1

CHEMICAL COMPOSITION OF NON-FERROUS SHEET SPRING MATERIALS

	Min., per cent	Max., per cent
Brass		
Copper	64.5	67.5
Lead	0.0	0.3
Iron	0.0	0.05
Zinc	Remainder	
Nickel Silver		
Copper	53.50	56.50
Nickel	16.50	19.50
Zinc	25.50	28.50
Iron	...	0.35
Phosphor Bronze		
Copper	91.0	...
Tin	7.50	8.50
Phosphorus	0.05	0.25
Iron	...	0.10
Lead	...	0.02
Antimony	...	0.01
Zinc	...	0.20

TABLE 2

MECHANICAL PROPERTIES OF NON-FERROUS SHEET SPRING MATERIALS

Brass

Thickness	Temper	B. & S. gage nos. hard	Tensile strength		Rockwell hardness "B" scale		Proportional limit	Modulus elasticity
			Min.	Max.	Min.	Max.		
0.40 in. and thicker	Hard	4	68,000	78,000	78	85	30,000	14×10^6
Below 0.40 in.	Hard	4	68,000	78,000	75	83		
0.040 in. and thicker	Spring	8	86,000	95,000	88	92	30,000	14×10^6
Below 0.040 in.	Spring	8	86,000	95,000	85	89		
0.040 in. and thicker	Extra spring	10	89,500	98,500	89	93		
Below 0.040 in.	Extra spring	10	89,500	98,500	86	90		

[2] "Physical Properties and Methods of Tests for Sheet Brass," by H. N. Van Deusen, L. I. Shaw, and C. H. Davis. Proceedings A.S.T.M., 1927.

Nickel Silver									
0.40 in. and thicker....	Hard	4	92,000	106,500	69	77	60,000	20×10^6
Below 0.40 in.	Hard	4	92,000	106,500	66	75		
0.040 in. and thicker....	Extra hard	6	102,000	115,000	75	82	60,000	20.0×10^6
Below 0.040 in.........	Extra hard	6	102,000	115,000	72	79		
0.040 in. and thicker....	Spring	8	108,000	120,000	78	84		
Below 0.040 in.........	Spring	8	108,000	120,000	75	81		
0.040 in. and thicker....	Extra spring	10	111,000	123,000	80	85		
Below 0.040 in.........	Extra spring	10	111,000	123,000	77	82		
Phosphor Bronze								
0.040 in. and thicker....	Extra hard	6	97,000	111,500	76	82	55,000	15×10^6
Below 0.040 in.........	Extra hard	6	97,000	111,500	73	79		
0.040 in. and thicker....	Spring	8	105,000	118,500	79	85		
Below 0.040 in.........	Spring	8	105,000	118,500	76	82		
0.040 in. and thicker....	Extra spring	10	109,500	122,000	81	86		
Below 0.040 in.........	Extra spring	10	109,500	122,000	78	83		

Note: The proportional limit and modulus figures are representative. They are only slightly changed by cold work.

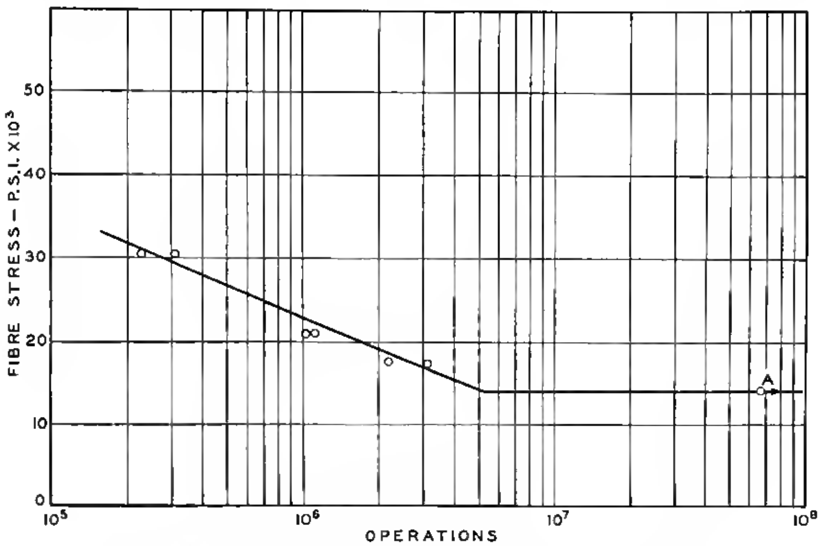

Fig. 2—Fiber stress vs. fatigue—brass sheet—24 gage—4 Nos. hard: *A*, average of three specimens taken from test without failure.

Fatigue Properties of Sheet Non-Ferrous Spring Materials

Because of the important bearing of fatigue of springs for telephone apparatus, this property has been carefully studied. The stress-

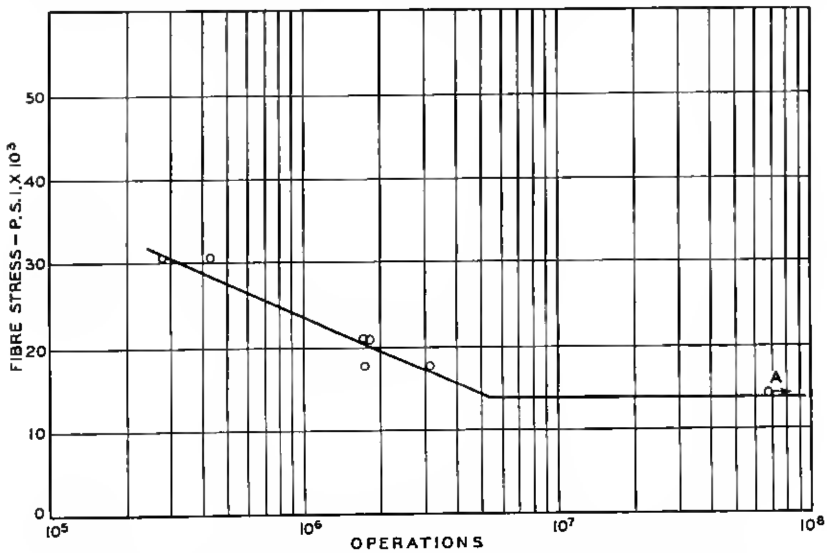

Fig. 3—Fiber stress vs. fatigue—brass sheet—24 gage—10 Nos. hard: *A*, average of three specimens taken from test without failure.

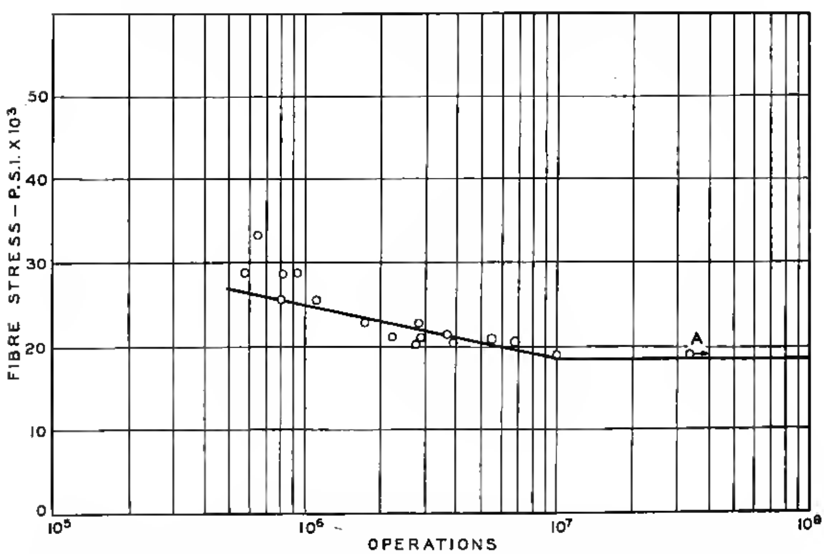

Fig. 4—Fiber stress vs. fatigue—nickel silver sheet—24 gage—4 Nos. hard: *A*, average of three specimens taken from test without failure.

cycle graphs shown by Figs. 2 to 6 give typical results. The design of specimen is shown by Fig. 7. These specimens were alternately stressed at the rate of 700 cycles per minute.

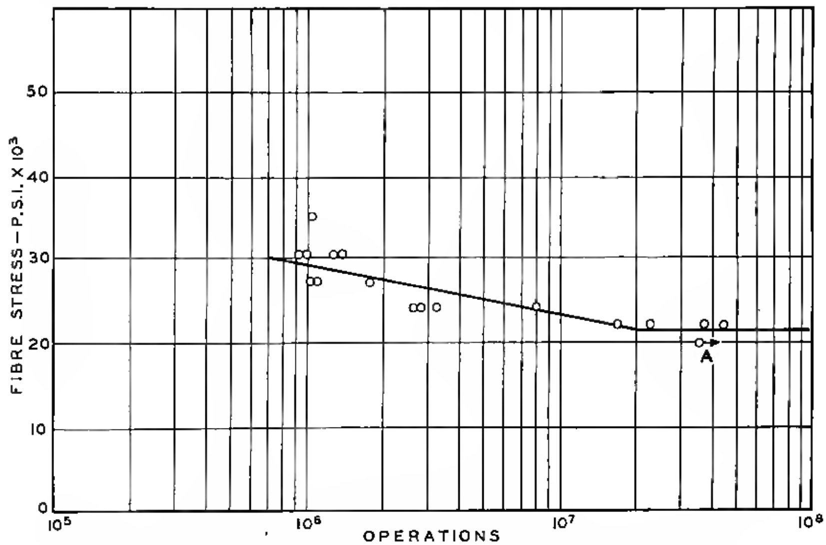

Fig. 5—Fiber stress vs. fatigue—nickel silver sheet—24 gage—10 Nos. hard: *A*, average of three specimens taken from test without failure.

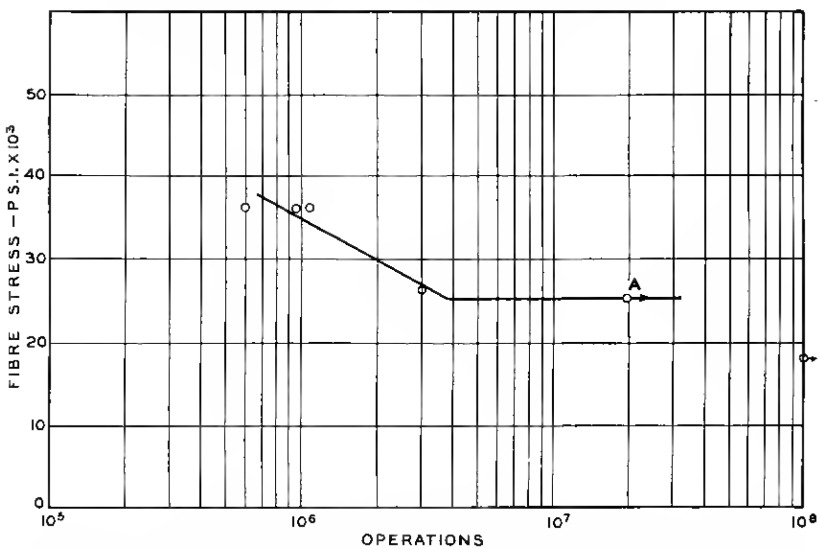

Fig. 6—Fiber stress vs. fatigue—phosphor bronze sheet—24 gage—10 Nos. hard: *A*, average of two specimens taken from test without failure.

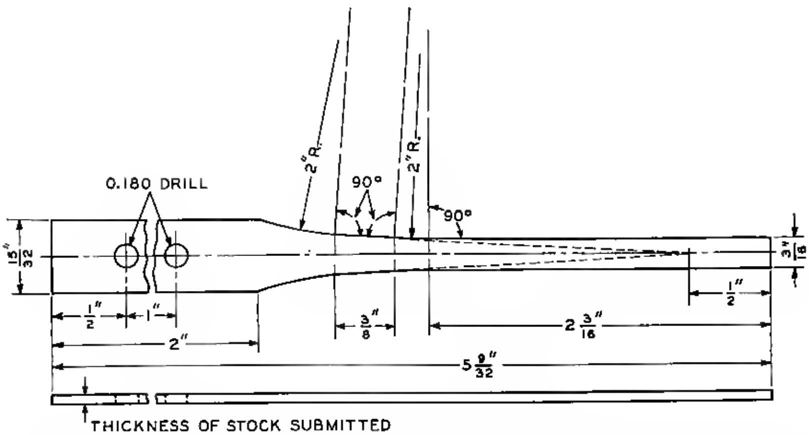

Fig. 7—Test specimen for fatigue study.

(The piece must be free from scriber and tool marks. The 2 in. radius fillets must join the tapered portion without an abrupt break. The intersection of the tapered sides produced must be ½ in. from the end.)

Clock-Spring-Steel Springs

These springs are used as vibrating elements in interrupters, where a high fatigue endurance is required, and for springs that must be worked at high pressures and rapid buildup. The material has the chemical composition shown by Table 3 and mechanical properties given by Table 4. This is a carbon-steel, heat treated and then cold rolled, and is by nature brittle. To guard against excessive brittleness and at the same time provide a high strength cold rolled steel, a bend test has been developed.

TABLE 3

Chemical Composition of Clock Spring Steel

	Min., per cent	Max., per cent
Carbon	0.85	1.15
Manganese	0.25	0.60
Silicon	..	0.22
Sulphur	..	0.025
Phosphorus	..	0.03
Nickel, chromium, tungsten	..	0.10
Vanadium	Optional	0.25
Iron	Remainder	

TABLE 4

Mechanical Properties of Clock Spring Steel

Ultimate strength	250,000 to 290,000 lb. per sq. in.
Proportional limit	160,000 to 215,000 lb. per sq. in.
Modulus of elasticity	27.6×10^6

The bend test requires that when the material is bent back parallel to itself to form a "U" and further compressed between flat parallel surfaces (for example, between the jaws of a vise), at a rate not to exceed 0.3 inches per minute, the material shall break along a straight line making approximately a 90 degree angle with the axis of the strip when the distance between the inside of the legs of the "U" is 25 to 16 times the thickness of the material. It must not break before the distance is reduced to 25 times the thickness of the metal. This test can be conveniently applied by drawing the looped material through two of a series of graduated slots.

Music Wire Springs

Tinned and plated music wire is extensively used for compression springs in telephone apparatus. Here the spring is in the form of an open helix. Fig. 8 shows a type widely used. These springs are either tinned or plated with nickel. It has been observed that the plating baths adversely affect the fatigue characteristics of music wire and this is under investigation at the present time.

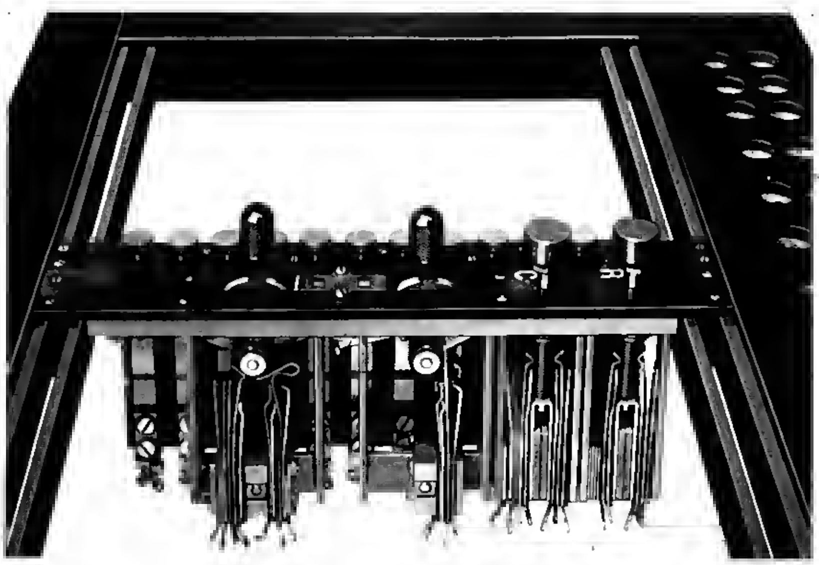

Fig. 8—Switchboard keys employing sheet metal springs and helical compression springs

The average tensile properties of the music wire employed are: proportional limit—217,000 lb. per sq. in.; ultimate tensile strength —350,000 lb. per sq. in. No chemical or tensile requirement is

placed on this wire, the main feature of concern being brittleness. The elongation measured in an 8 in. length must be between 1 and 4 per cent for wire up to and including No. 27 gage and $1\frac{1}{2}$ to 7 per cent for No. 28 gage wire and heavier. The wire is also subject to a kinking test in which No. 30 wire and smaller shall kink without breaking. This last test indirectly controls the tensile properties of the wire.

Summary

A review has been given of the more common types of telephone apparatus springs. Vast quantities of these springs are employed in the telephone plant and the numerous factors that must be considered with regard to selecting material have been reviewed. The materials most generally used have abundant competitive sources of supply and the quality is carefully controlled by tests that are designed to be easy to apply and effective in evaluating the properties desired.